Documenting Fine-Sediment Import and Export for Two Contrasting Mesotidal Flats
Sediment Flux through the Mekong Tidal River, Delta and Mangrove Shoreline
Instrumentation to Support Investigation of Large Tropical Deltas

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LONG-TERM GOALS

The general goal of these projects is to examine the seabed, quantitatively document the fluxes of fine sediment (over different time scales), and thereby validate localized measurements and numerical models of sediment transport for diverse tidal systems (tidal flats, mangrove forests, deltaic distributaries).

OBJECTIVES

The specific objectives are to:

a) document changes in bed elevation (deposition, erosion) on time scales intrinsic to the driving forces; e.g., tidal and wind-driven currents, local waves, river discharge, and interannual variability;

b) measure net accumulation rates over decades at many sites to calculate fine-sediment budgets for intertidal settings in Washington State (Willapa and Skagit Bays) and Vietnam (Mekong Delta);

c) examine sedimentation at sufficient locations to characterize spatial variability of grain size and its vertical stratification.

In addition, these grants were responsible for coordination of the Tidal Flats project and helping to plan research on the Mekong delta.

APPROACH

Tidal-flat sedimentation on Willapa mud flats and Skagit sand flats was contrasted, and the results published. As coordinator for the Tidal Flats DRI, I led the organization and production for a special issue of Continental Shelf Research.

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We have initiated studies of the Mekong delta system. These are focused on investigation of sedimentary dynamics within the Song Hau distributary channel, including the estuarine turbidity maximum, suspended and bed sediment, and variations of these on tidal and seasonal time scales. Associated intertidal environments (tidal flats, mangrove forests) were identified for intense study in the future, and some initial measurements were obtained.

In preparation for a future coordinated ONR study of the Mekong delta, collaborations were developed with Vietnamese scientists and logistical considerations were explored for future field studies

WORK COMPLETED

"*Hydrodynamics and Sedimentation on Mesotidal Sand- and Mudflats"* was published in June 2013 as Volume 60 of Continental Shelf Research. It includes 17 ONR-funded papers about Willapa and Skagit tidal flats, including 3 papers that are a direct result of this grant.

Two expeditions were completed to the Song Hau distributary channel of the Mekong Delta in Aug-Sep 2012 and Apr 2013. During both, samples of the channel bed were collected in conjunction with flow measurements by a research project led by Dr. Andrea Ogston, and adjacent mangrove forests were explored and cored. The focus in 2012 was on a forest along the south channel, and in 2013 was on the mangrove forest along the ocean front.

Workshops were held with Vietnamese scientists at Can Tho University (in Can Tho), Vietnam National University (in Ho Chi Minh City); and the VAST Institute of Marine Geology & Geophysics (in Hanoi). In addition, CTU and IMGG personnel visited our laboratories at the University of Washington.

RESULTS

Song Hau distributary channel

The field study completed in late August and early September 2012 was focused on high-flow conditions of the Song Hau, and the work in April 2013 was during low-flow conditions.

In Aug-Sep 2012, our studies were coordinated with ADCP and CTD transects in the channels on the northeast and southwest sides of Cu Lao Dung (CLD) island designed to characterize flow and water-column structure both spatially and temporally. During transects, bathymetric profiling and river-bed characterization (sediment sampling) was also accomplished on both sides of CLD island. Two 25-hour occupations of transects were surveyed across the northeast channel, one transect (B) in the region of salt wedge (exhibiting vertically sheared flow and a turbidity maximum) and the other transect (A) upstream in the tidal river (above the extent of salt-water intrusion and in the region of reversing flow, during high-river flow). The bed of the river was thoroughly sampled for spatial variability in the channels on both sides of CLD island, and sampled for temporal variability along the 25-h transects.

In Apr 2013, we reoccupied the two transects (A and B), both in the channel on the northeast side of CLD island. We added a third transect, C, as far upstream as possible. However, we were constrained by study-area permissions. Transect C was 8 km above CLD island, and is in a single thread of the river (no islands). On each transect, we ran continuous ADCP surveys in a northeastward direction, and came back southwestward with the ADCP running. As with the Aug-Sep 2012 field work, we

stopped at three repetitive cross-channel stations to make CTD-OBS profiles, collect water (top and bottom) for filtration, and recover seabed samples. It generally took less than an hour for a roundtrip survey, and we did them for 25 hours each.

The preliminary data provide a good understanding of seabed character within the local estuarine context, as well as insights about fluctuations over seasonal and diurnal tidal time scales.

1) *salt wedge* – During the Aug-Sep survey, transect B was more or less in the area of the estuarine turbidity maximum (although the ETM moved with the tides). At that time, we saw maximum salinities in the teens. During Apr low-flow conditions, maximum salinities were in the twenties at transect B and reached fully oceanic salinities (~35) at the seaward end of the channel. In Aug-Sep, salt did not reach transect A. In Apr, it reached Transect C (salinity 2-11, low-high tide, respectively).

2) *bed grain size* – The bed of the middle transect A was distinctly muddier in Apr than during Aug-Sep. During the high-flow survey, transect A was above the estuarine turbidity maximum and the bed was sandy – even hard pan in the deepest channel. When the salt wedge penetrated upstream in Apr, it brought the ability to trap and deposit muddy suspended sediment. This mud is likely transported landward from the continental shelf.

3) *bathymetry* – A simple single-beam depth finder gave good cross-channel bathymetric data from multiple passes at locations of the three transects. The cross-channel shapes show variety. Transect B has two channels (deepest ~15 m) on either side of a mid-channel shoal (~6 m deep). Transect A has a single channel with an asymmetric cross section – a deep channel (~15 m) hugging the northeast bank, rising gently to the southwest. Transect C has three channels, separated by two shoals that are submerged extensions of nearby islands.

Cu Lao Dung mangrove shorelines

During the Aug-Sep 2012 field work, we focused on finding small channels through the river banks, and discovered that the mainland banks and CLD shorelines are thoroughly diked with only thin fringes of vegetation. We did find one small area of young mangrove forest on the southeast corner of CLD island, and were able to document the rapid accumulation of physically laminated muds.

During Apr 2013 field work, we investigated the ocean front of CLD island. An intertidal flat and a subtidal shoal are found in front of a mangrove forest. The bottom is soft mud on the flat and in the forest, and both areas are accreting. The forest has young and old Avicennia mangroves that are very healthy, and show little or no disturbance from humans. Within the forest, there are runnels similar to those on the Willapa flat, and they converge and deepen seaward. There are ripples throughout the forest floor, likely from surface waves. Barnacles on the mangrove trunks indicate tidal water levels ~1.5 m deep throughout much of the forest.

TRANSITIONS

For the Tidal Flats DRI, the results of this effort were transferred to many other investigators interested in seabed processes. Researchers who analyzed boundary-layer processes utilized our data to understand bed erosion and deposition. Accumulation rates, sediment budgets, and grain-size data were key components to input parameters for numerical models. Similarly, as the Mekong study grows, others are expected to use our observations for ground truth in remote sensing and validation in numerical models.

RELATED PROJECTS

Related projects in the Tidal Flats DRI included studies of: the seabed by R. Wheatcroft and P. Wiberg; boundary-layer processes by A. Ogston, R. Geyer, P. Traykovski, and D. Ralston; suspended-sediment dynamics by P. Hill, B. Law and T. Milligan; seabed thermal processes by J. Thomson and C. Chickadel.

Related projects in the Tropical Deltas DRI are underway by A. Ogston, E. Terrill, and D. Roelvink.

PUBLICATIONS (written)

Boldt, K.V., C.A. Nittrouer, and A.S. Ogston., 2013, Seasonal transfer and net accumulation of fine sediment on a muddy tidal flat: Willapa Bay, Washington, *Continental Shelf. Research*, dx.doi.org/10.1016/j.csr.2012.08.012.

Nittrouer, C.A., B. Raubenheimer, and R.A. Wheatcroft, 2013, Lessons learned from comparison of mesotidal sand- and mudflats, *Continental Shelf Research*, dx.doi.org/10.1016/j.csr.2013.03.003.

Webster, K.L., C.A. Nittrouer, and A.S. Ogston, in preparation, Fluvial sediment dispersal through an insular sea: modern sedimentation associated with the Skagit River delta, *Marine Geology*.

Webster, K.L., A.S. Ogston, and C.A. Nittrouer, 2013, Delivery, reworking and export of fine-grained sediment across the sandy Skagit River tidal flats, *Continental Shelf Research*, dx.doi.org/10.1016/j.csr.2012.11.002**.**